Tonan Ajia Kenkyu (*The Southeast Asian Studies*) Vol. 7, No. 4 March, 1970

Some Properties of Soils and Substrata in the Lampang Basin

by

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The author has studied the relationship between geomorphic features and soils, especially the weathering history of soil constituents, and has reported on this subject with reference to paddy soils in the northern basins of Thailand and in Cambodia.[1,2] Relationship between the stratigraphical sequence and clay mineral compositions of the Quaternary sediments in the Central Plain of Thailand have been studied.[3] The studies indicate that the constituents of soils and sedimentary deposits reflect the history of weathering during their formation. The degree of development of iron nodules and concretions, regarded as weathering features, and the clay mineral composition, especially kaolin mineral contents, in the deposits are also closely related to certain geomorphic features. The results suggest that the geomorphic features and the soils in the plain developed by cycles of soil formation, erosion, transportation and sedimentation processes, caused by the alteration of climate and the tectonic movement during the Quaternary Period.

In this paper some properties such as (1) clay mineralogy, (2) colour, (3) etc. of the constituents of soils and substrata are reported as the basic data for the explanation of development of soils and geomorphic features in the Lampang basin in the northern Thailand.

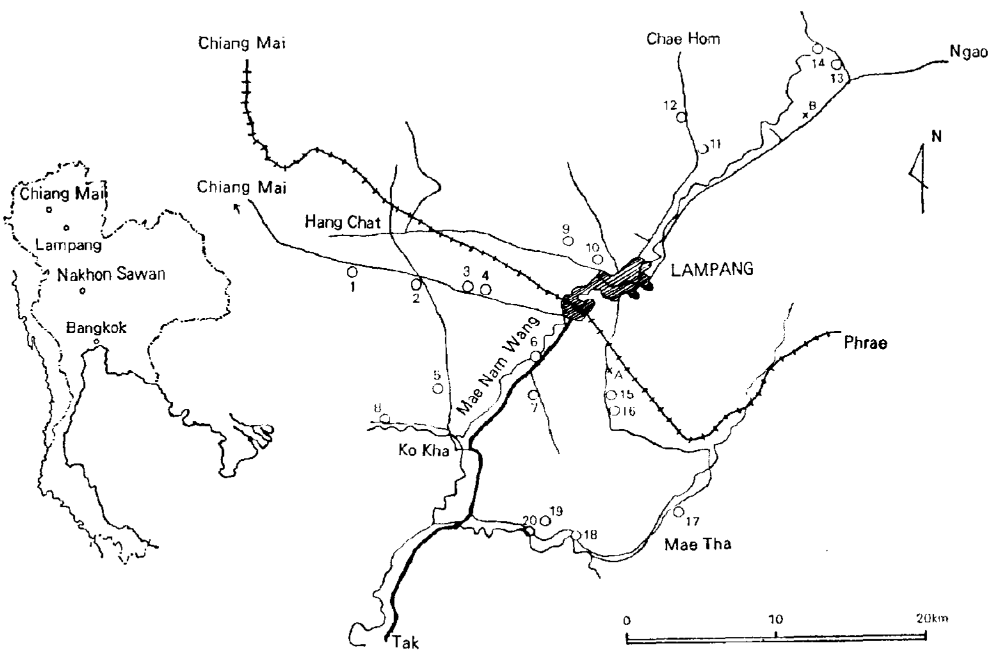

Fig. 1 Sampling sites in Lampang basin

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I Outlines of survey area and samples

As details of geographical, geomorphological and geological descriptions of the survey area will be shown in another place, here a brief sketch of the area and samples are given.

Figure 1 shows the approximate sites of the outcrops observed in the Lampang basin. These sites are grouped geographically into six as shown in Table 1.

Table 1 Geographical grouping of observed outcrops

Physiographical region	Outcrop number
Central flat plain	No. 5, 6, 7
West marginal plain	No. 1, 2, 3, 4
South-west marginal plain	No. 8
North marginal plain	No. 9, 10
South and south-east marginal plain	No. 15, 16, 17, 18, 19, 20
North-east marginal plain	No. 11, 12, 13, 14

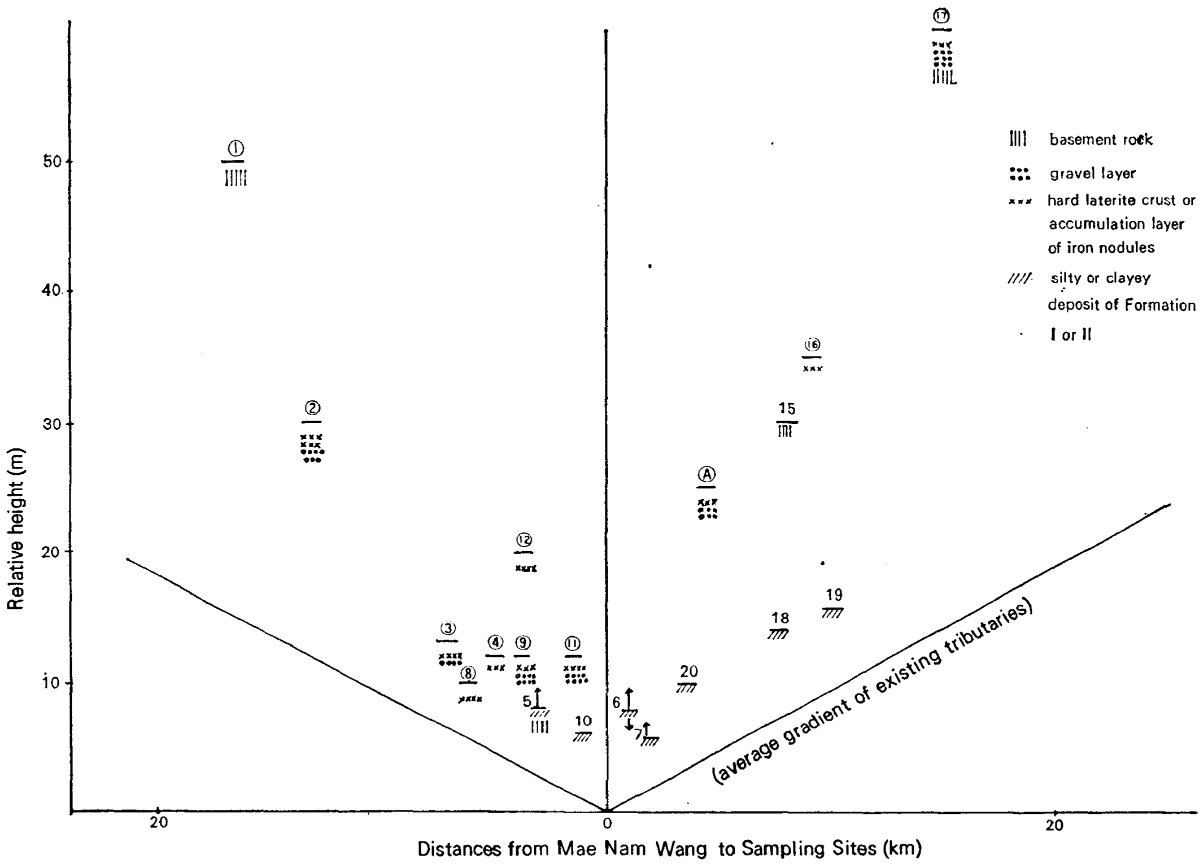

Fig. 2 Relation between the relative heights and distances of outcrops from Mae Nam Wang

As no detailed geological maps are available, the geology of the survey area is not known exactly. The field observations, however, indicated that mountains to the east of the Lampang basin are rich in basic igneous rocks while those to the west are mainly of acidic rocks.

A geomorphological analyses of survey area was attempted to make clear the relation among the geomorphic surfaces composing the Lampang basin. The distances from the Mae Nam Wang to the sites of outcrops and the relative heights of these sites above the river are shown in Figure 2. No clear relation is seen on the right bank of the river, but two more or less clear surfaces can be visualized by connecting two sets of outcrop sites on the left bank. One of these surfaces is nearly parallel to the average gradient of the existing tributaries of the Wang and composed of the outcrops characterized by silty or clayey sediments. The other surface has a steeper gradient than the reference gradient and is composed of the outcrops having a hard laterite crust or a layer of accumulation of ferruginous nodules and concretions. What is seen here may suggest that the time of formation of the clayey sediments is recent, whereas those sediments with laterite or layers of iron concretions may have been formed in the geological past and thus experienced uplifting in the ridge of mountains and subsiding in the center of the basin after the formation of the surface.

The geomorphic and stratigraphic positions of the observed outcrops are shown schematically in Figure 3 based on the inference from both their profile and stratigraphic features. The characteristics of each layer of outcrops are listed in Figure 4. If one attempts to fit these outcrops into Takaya's scheme,[4] which was proposed on the basis of a field survey of the Quaternary outcrops in central Thailand, five formations can be recognized in the Lampang basin. The characteristics of each formation are as follows.

1. Flood plain (natural levee and back swamp) distributes only along the Mae Nam Wang; no outcrops were observed.

2. Terrace I is composed of silty deposits, containing no iron nodules and concretions but sometimes graphites and weathered fragments of bricks and potteries. It occurs as a strip along the Wang and the main tributaries. It is utilized as homesteads and vegetable gardens. Outcrops No. 18 and 20 are located on this unit.

3. Terrace II is the major paddy area in the Lampang basin. It has a flat to slightly undulating landform. The deposits are clayey with small pisolitic concretions of iron and manganese. Low humic gley soils are developed on this unit. Outcrops No. 5, 6, 7, 10, 14 and 17 are located on it.

4. Terrace III has an undulating to rolling landform. The terrace surface gradually decreases its height towards the center of the basin. This unit is utilized only partly as paddy or upland fields but mostly consists of waste land with sparse small bushes. The following three sediments are found in Terrace III according to the nature of the near surface sediments.

4a) The first is sandy deposits, on which red yellow podsolic-like soils have developed, underlain by gravel layers mixed with clay. The upper part of the gravel layers have sometimes a hard laterite crust or an accumulation layer of iron nodules and concretions. Outcrops No. 9, 10, 12, 16 and 17 belong to this subunit.

4b) The second is composed of three parts—the upper part consists of sandy deposits, on which red yellow podsolic or gray podsolic-like soils have developed, the middle part has hard laterite crusts or accumulation layers of iron nodules and concretions, and the lower part is composed of sandy clay deposits with plinthitic mottles. Outcrops No. 2, 3 and 4 may belong to this subunit.

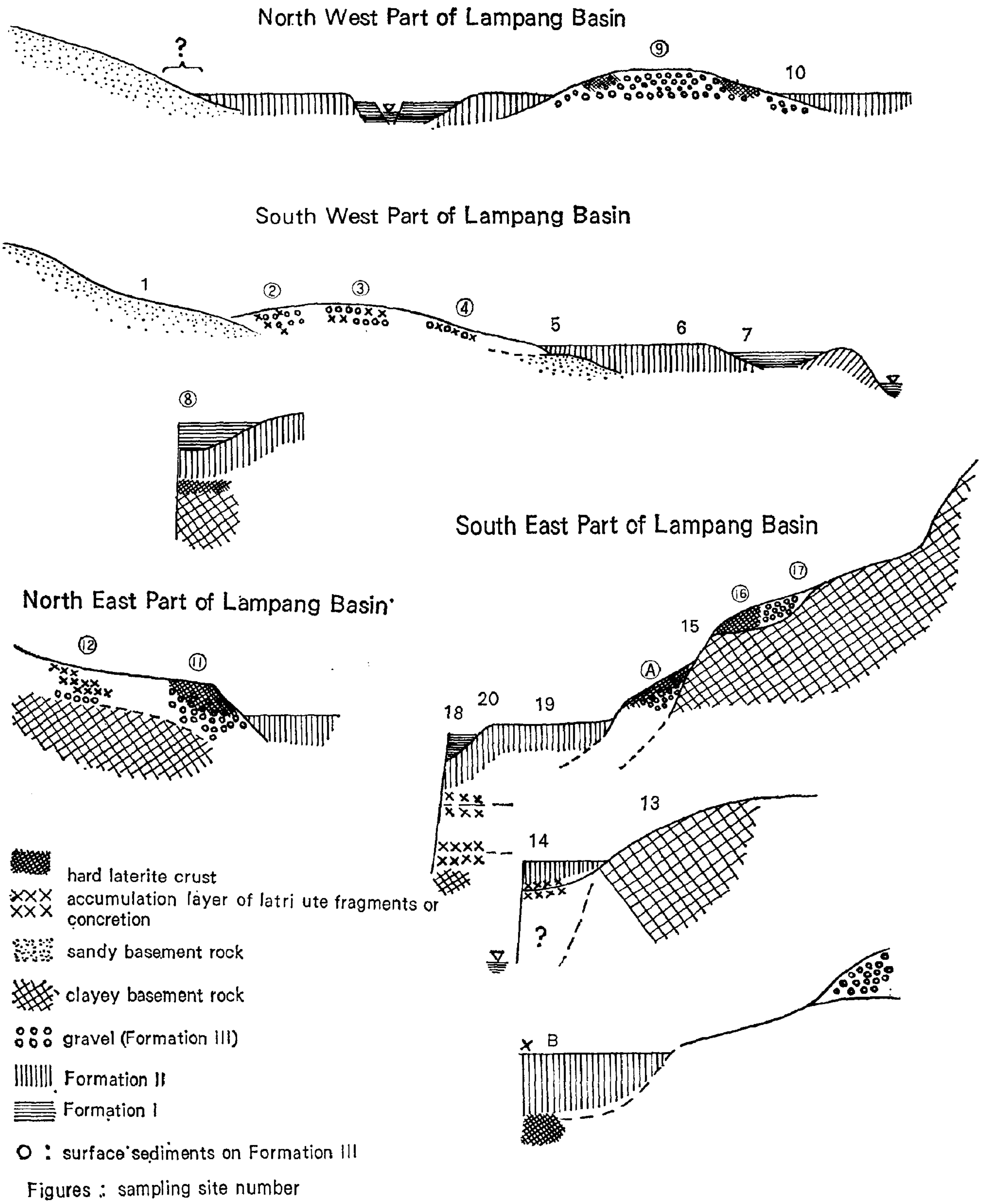

Fig. 3 Geomorphological and stratigraphical setting of outcrops

4c) The third subunit consists of accumulation layers of iron nodules and concretions, underlain by clayey deposits with plinthitic mottles. The substrata of outcrop No. 14 and 18 are the examples.

In the profiles of red yellow podsolic or gray podsolic-like soils the matrix of the upper horizons just above the hard laterite crusts or the accumulation layers of iron nodules and concretions is similar to that of surface horizons, except that the former contains many nodules and concretions.

5. A unit consisting of a peneplain and exposed weathered rock occurs between the Terrace III and mountains. Grumsolic and reddish (Pak Chong series) soil have been formed on the east side of the basin while on the west side gray podsolic-like soils, which resemble the soils on Terrace III have been developed on this unit. Occasionally, weathered basement rocks, which underlie Formation III, are exposed on steep slopes. The colour of the weathered materials is

Table 2 Physiographical and stratigraphical grouping of samples from each outcrops

		Central	West	South-west	North	North-east	South & South-east
Terrace I (Formation I)							No. 18-1 No. 20-1 No. 20-2
Terrace II (Formation II)		No. 5-1 No. 6-1 No. 7-1 No. 7-2		No. 8-2?	No. 10-1	No. 14-1	No. 18-2 No. 18-3 No. 19-1 No. 20-3
Terrace III, Formation III	a				No. 9-3 No. 9-5 No. 9-6		No. 17-4 No. 17-5 No. 17-6
Terrace III, Formation III	b		No. 3-3 No. 3-4 No. 4-3 No. 4-4 No. 4-5	No. 8-3? No. 8-4?			
Terrace III, Formation III	c					No. 14-2 No. 14-3 No. 14-4	No. 18-4 No. 18-5
Terrace III	Surface deposits		No. 2-1 No. 2-2 No. 2-3 No. 2-4 No. 3-1 No. 3-2 No. 4-1 No. 4-2		No. 9-1 No. 9-2 No. 9-3	No. 11-1 No. 11-2 No. 11-3 No. 11-4 No. 11-5 No. 12-1 No. 12-2 No. 12-3 No. 12-4 No. 12-5	No. 17-1 No. 17-2 No. 17-3 No. 16-1
Basement Peneplain		No 5-2 No. 5-3	No 1-1 No. 1-2 No. 1-3			No. 13-1 No. 13-2 No. 13-3 No. 13-4	No. 15-1 No. 15-2 No. 15-3 No. 17-7 No. 17-8

generally reddish on the east side and grayish white on the west side of the Lampang basin. Outcrops No. 1, 13 and 15 are located on the peneplain or weathered rocks; the lower part of outcrops No. 5 and 17 are the exposures of weathered basement rocks.

Each layer of the observed outcrops was assigned to one of the physiographic units, as shown Table 2. Assignment of the layers of outcrop No. 8 were somewhat ambiguous, but they were tentatively assigned using the accumulation layer of iron nodules and concretions as a key bed.

II Some properties of deposits of Terraces and the weathered rocks

The particle size distribution of the samples was analyzed by the method for mechanical analysis and the texture and silt clay ratio were determined. The clay mineralogical composition was determined by the X-ray diffraction method.[5] The mineralogical characteristics of coarse sand fractions were assessed by a naked-eye observation. Figure 4 shows the results.

Judging from the particle size distribution and clay mineral composition, the weathering products of basement rocks on the east side of the Lampang basin differ markedly from those on the west side. On the west side the predominant clay mineral is kaolin. Among the accessary minerals of 2:1 type, illite is relatively minor as compared to montmorillonitic clays. On the east side the clay contents are very high (above 70 per cent), in which kaolin is the dominant mineral, occupying about 50 per cent of the total clay. Illite content is about 20 per cent and the rest is 2:1 type minerals, in which vermiculite dominates in the samples from outcrop No. 13, consisting mainly of unweathered rock fragments. This fact may indicate that the source rock on the east side differs from that on the west side. Indeed, as mentioned before, the weathering products on the east side are often strongly red-coloured in contrast to those on the west side which are grayish white in colour. This colour difference probably indicates different parent source rocks for these soils.

The silt clay ratios and the breadth of the kaolin peak can be used as the indices of the degree of weathering. The surface layer samples, which constitutes the uppermost parts of weathered basement rocks, have a wide d_{001} kaolin meneral peak on X-ray diffraction diagrams of the samples from the outcrop No. 15, as shown in Figure 5, and the silt clay ratio is narrower compared to those for the lower layer samples (No. 1). The same relations holds for the three layers of the outcrop No. 13, the surface layer of which contains in its coarse sand fraction many reddish-brown coloured, irregular-shaped grains commonly seen in the deposits of Terrace III, thus may not be considered to be of the same origin as the lower layers. From this result, it may be said that the narrower the silt clay ratio and the more the clay formed from the larger primary minerals, the wider the breadth of d_{001} peak of kaolin mineral, that is, the smaller the crystallites and the poorer the crystallinity of kaolin mineral. Silt clay ratios, used as an index of the weathering degree, appeared in a paper which dealt with the soils in Africa that developed on different terrace deposits whose materials are of the same origin.[6] An example in which the breadth of d_{001} peak of clay minerals is used as an index is found in a paper which reported on the weathering of montmorillonite in acid soils and weathering products in the green tuff region of Japan.[7]

The silt clay ratio of upper part of deposits is also modified by various factors, such as condition of sedimentation, clay leaching and erosion. Thus, care must be taken. Generally speaking, however, the presence of a great break or a conspicuous discontinuity in the silt clay ratio

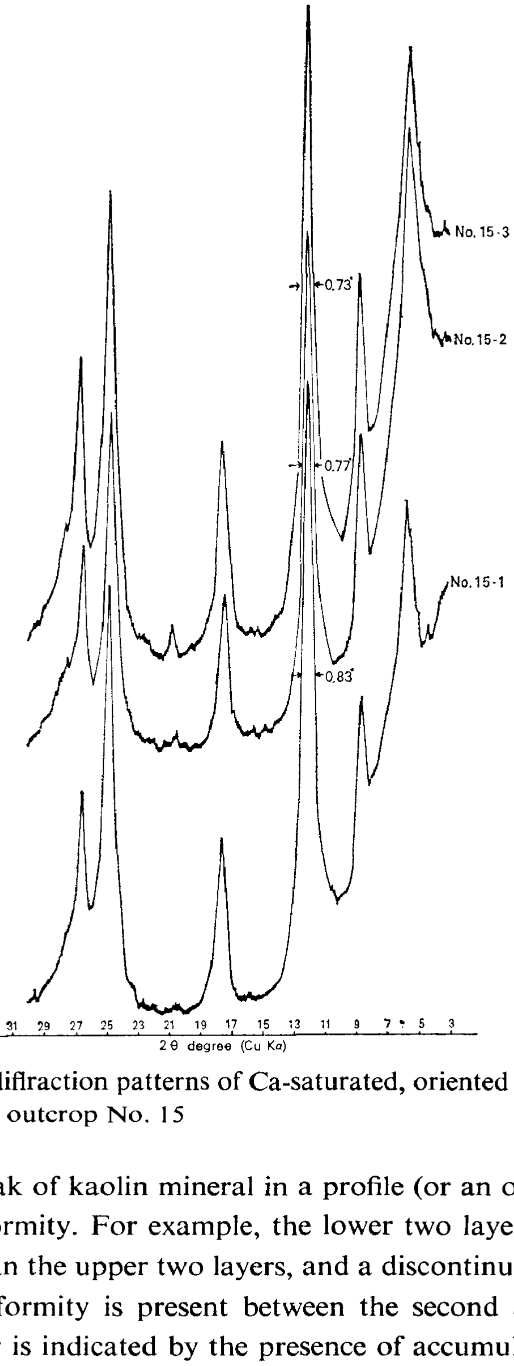

Fig. 5 X-ray difiraction patterns of Ca-saturated, oriented clay specimens from the outcrop No. 15

or in the breadth of d_{001} peak of kaolin mineral in a profile (or an outcrop) may be considered as an indication of unconformity. For example, the lower two layers of the outcrop No. 2 are more severely weathered than the upper two layers, and a discontinuity in the weathering indices, thus presumably an unconformity is present between the second and the third layers.

When an unconformity is indicated by the presence of accumulation layers of iron nodules and concretions, these two values may be used to determine whether the upper or the lower boundary of this layer is the unconformity. For instance, in the outcrop No. 14, the silt clay ratios decrease and kaolin mineral contents increase from the lowest to the uppermost layer but the breadth of d_{001} peak of kaolin mineral is largest in the accumulation layer of iron nodules and concretions. This discontinuous change may indicate that the accumulation layer has the most advanced weathering degree as compared to the upper or lower layers and the concretions were formed *in situ* by weathering in some old days, when this layer underwent a severe subaerial weathering. Therefore the upper boundary of this layer can be regarded as the plain of unconformity. On the other hand, when the accumulation layer of iron nodules and concretions of the outcrops No. 8 and 18 is compared with the upper and lower layers, the silt clay ratio, the breadth of d_{001} peak of kaolin mineral and kaolin mineral content of the former are intermediate between or almost identical with those of the latter. This result may indicate that the accumulation layer is formed as a result of mixing of the upper and lower layer materials, and the nodules and concretions are not the *in situ* weathering products. Namely the lower boundary of this layer may be assumed to be the plain of unconformity.

When such consideration as stated above is applied to all the observed outcrops, it is possible to assign for each of the different layers an adequate position in a geographical-physiographical system of classification. The result is shown in Table 3. Here only a broad bifurcation into the east and west parts is adopted as the geographical subdivision of the area. The result obtained herein is, with only few exceptions, in very good agreement with that given in Table 2, which is solely based on the field observations.

Table 3 also gives a generalization with respect to the chemical nature of the materials of different physiographic units. Several summarizing comments are given in the following:

1. As already stated, the weathering products in the Lampang basin are different in nature between the eastern and western halves.

2. The materials of each formation show similar properties within the same geographic subdivision.

3. The deposits of Formation III consist of three kind of materials, 4a, 4b and 4c, which correspond respectively to the deposits containing many gravels, sandy clay deposits having plinthitic mottles and the deposits having an accumulation layer of iron nodules and concretions which underlies the Formation II.

4. The degree of weathering of the deposits advances in the order Formation I<II<III.

5. The surface deposits on Terrace III are not only less weathered than the deposits of Formation III proper, but also show greatly different properties from those of the deposits of Formation I and II.

6. Mineralogical characteristics of coarse sand fractions of the surface deposits on Terrace III show an extremely advanced weathering feature. Their kaolin mineral contents also are high. However, their illite contents among accessory 2:1 type clay minerals are relatively high as compared to the samples of the outcrop No. 1 and Formation III, whose mineralogical characteristics are similar to those of the surface deposits. Moreover, judging from the weathering indices such as kaolin mineral contents, silt clay ratio and breadth of d_{001} peak of kaolin mineral, the uppermost material is less weathered than the materials below within the thickness of the surface deposits. From these facts it may be said that the surface deposits on Terrace III have contradictory nature, i. e., a advanced weathering feature in the coarser fraction and a retarded weathering feature in the relatively illite-rich fraction. Thus, we may have to assume different mechanisms of sedimentation for these two fractions of the surface deposits.

7. The accumulation layers of iron nodules and concretions, which serve as the key bed for determining the plain of unconformity in the field, appear to have been either formed *in situ* but strong weathering on ground surface or transported and mixed with the underlying materials.

8. The geomorphic feature of a surface and the nature of the materials composing it are closely

Table 3 Characteristics of samples grouped physiographically and stratigraphically

			West Part	East Part
Terrace I	Formation I			Texture: CL–SiC, silt/clay: 2.40–1.80, kaol: 40% Ill: 25–30%, b_k: 0.61–0.63° (No. 18-1, No. 20-1)
	Formation I mixed with Formation II			Texture: SiC, silt/clay: 1.23, kaol: 40%, Ill: 30% b_k: 0.57° (No. 20-2)
Terrace II	Formation II		Texture: CL–HC, silt/clay: 0.95–1.45, kaol: 45–50% Ill: 15–35%, b_k: 0.73–0.83° (No. 5-1, No. 6-1, No. 7-1,2, No. 10-1)	Texture: SiC–HC, silt/clay: 0.68–1.18, kaol: 40–56% Ill 20–25%, b_k: 0.57–0.61° (0.82) (No. 14-1, No. 18-2, 3, No. 19-1, No. 20-3)
	Formation II mixed with Formation III			Texture : HC, silt/clay: 0.80, kaol: 50%, Ill 25% b_k: 0.69° (No. 18-4)
Terrace III	Formation III	a	Texture: LiC, silt/clay: 0.16–0.21, kaol: 80–85% Ill: 15%, b_k: 0.74–0.99°, Ver>Mt (No. 9-4, 5, 6)	Texture: LiC, silt/clay: 0.38–0.40, kaol: 60–65% Ill: 10%, b_k: 0.65–0.76°, Ver>Mt (No. 17-4, 5, 6)
		b	Texture: SC–HC, silt/clay: 0.23–0.30, kaol: 70–90% Ill: 5–20%, b_k: 0.79–0.99°, Ver>Mt (No. 3-3, 4, No. 4-5)	
		c		Texture: LiC, silt/clay: 0.77–0.81, kaol: 45–55% Ill: 25–30%, b_k: 0.96–1.05°, Ver>Mt (No. 14-2, 3, 4, No. 18-5)
	Surface Sediments	Lower part	Texture: SL–SC, silt/clay: 0.08–0.64, kaol: 75–90% Ill: 5–15%, b_k: 0.79–0.83°, Ver>Mt (No. 2-3, 4, No. 4-3, 4, No. 9-3)	Texture: LiC–HC, silt/clay: 0.21–0.56, kaol: 60–70% Ill: 10–15%, b_k: 0.63–0.70°, Mt≧Ver (No. 12-4, 5, No. 17-3)
		Upper part	Texture: LC–SL, silt/clay: 0.31–1.36, kaol: 70–90% Ill: 5–25%, b_k: 0.71–0.93°, Ver>Mt (No. 2-1, 2, No. 3-1, 2, No. 4-1,2, No. 9-1,2)	Texture: SL–LiC, silt/clay: 0.83–1.40, kaol: 55–70% Ill: 5–20%, b_k: 0.50–0.70°, Mt≧Ver (No. 12-1, 2 , 3, No. 16-1, No. 17-1, 2)
Basement	Weathered		Texture: SC, silt/clay: 0.30–0.37, kaol: 90% Ill: trace, b_k: 0.84°, Mt>Ver (No. 1-1, 2, 3,)	Texture: HC (clay: >70%), silt/clay: 0.09–0.72, kaol: 50–65%, Ill: 20–25%, b_k: 0.51–0.83°, Ver>Mt (No. 15-1, 2, 3, No. 17-7,8)
	Unweathered		Texture: S–HC, silt/clay: 0.32–1.17, kaol: 55–60% Ill: 15–20%, b_k: 0.83–1.14°, Mt≧Ver (No. 5-2, 3, No. 8-4)	Texture: S, silt/clay: 1.10–2.24, kaol: 25–35% Ill: 20%, b_k: 1.10°, Ver>Mt (No. 13-2, 3, 4)

Texture: S: sand, SL: sandy loam, SC: sandy clay, CL: clay loam, SiC: silty clay, LiC: light clay, HC: heavy clay
Clay minerals: kaol: kaolin mineral, Ill: illite, Mt: Montmorillonite, Ver: Vermiculite
b_k: the half maximum breadth of d_{001} peak of kaolin mineral (degree)

related with each other; indices such as the silt clay ratios, kaolin mineral contents and breadth of d_{001} peak of kaolin mineral, give a clue for dissolving the relation.

III Some consideration on the periods of sedimentation of each deposit

It has been shown that each geomorphic unit has been formed under similar conditions and its constituents have undergone similar weathering processes. As no fossils have been found in any of these deposits, the time of the terrace formation is not readily determined. However, it is possible to correlate these physiographic units in the Lampang basin with those in the Central Plain of Thailand, for which Takaya[4] already proposed age relationships. According to Takaya's scheme, the time of the formation of Flood Plain, Terrace I, II and III may correspond to upper Holocene, lower Holocene, upper Pleistocene and middle Pleistocene, respectively.

Although the surface deposits on Terrace III are thought to be of eolian origin by Takaya, the materials are so sandy that it is difficult to assume their eolian origin. The fact that the surface deposits on Terrace III show, as mentioned above, somewhat contradictory properties seems to suggest that the mechanism of sedimentation of silty illitic and sandy kaolinitic materials may be different. For the confirmation of this inference, more detailed studies must be conducted, such as proving of eolian origin by the examination of 0^{18}-values of quartz particles in the silt fraction.[8] But, if some part of the surface deposits on Terrace III were of eolian origin, the process of formation Terrace III would have been as follows: after the gravel bed or the sandy clay layer had been laid down and strongly weathered, the layer of the sandy material which contains pink quartz and acidic weatherable minerals was deposited by water during a humid period and subsequently weathered finally to leave the heavily weathered coarse sand and kaolin minerals. Then, during the following arid cycle the silty illitic materials was wind-blown and mixed with the then surface material to form the present surface layer. If the silty illitic materials have been continuing to fall on the ground from the time of Terrace III formation to the present, they must have been accumulating on every terrace and flood plain. But apparently this is not the case. This may be explained by assuming either a water erosion on Terrace II, I and Flood Plain, all of which undergo seasonal flooding during the rainy season, or a mixing of the wind-blown materials with the surface materials of these plains which are more or less depositional in nature.

On the other hand, the surface deposits on Terrace III have remained typically as the wind-blown sediment. As the coarse sand fractions of the surface layers of almost all the outcrops contain many quartz grains and reddish brown-coloured, irregular shaped particles which are characteristics of the wind-blown sediment, it may be thought that the ground surface of the Lampang basin are everywhere influenced by the similar material.

Furthermore, one question arises as to the stratigraphical sequence of peneplains and weathered rocks, such as those occuring the outcrop No. 1 and the lowest layers of the outcrop No. 5 and 8. But this point will be clarified only after more detailed surveys are carried out.

In order to explain the developments of geomorphic features in the Lampang basin with reference to the pedological chronology, not only the geomorphological, geological and paleo-climatological analysis of the area but also the elucidation of the influence of soil forming processes exerted on each deposits should first be done.

IV Summary

Based on the results a field survey and laboratory experiments, the Quaternary deposits in the Lampang basin, northern Thailand, were grouped into six physiographic units. The time of the formation of these six units is estimated according to Takaya's scheme as follows:

1.	Flood Plain	Upper Holocene
2.	Terrace I	Lower Holocene
3.	Terrace II	Upper Pleistocene
4.	Terrace III	Middle Pleistocene
5.	Surface deposits on Terrace III	?
6.	Peneplain	

It was shown that the silt clay ratios, kaolin mineral contents and breadth of d_{001} peak of kaolin mineral in the X-ray diffraction diagram can be used as indices of weathering degree. Using these indices it is clear that the accumulation layers of iron nodules and concretions were formed either by *in situ* weathering or by transport and deposition.

Acknowledgement

This report is part of a field survey and laboratory study of Quaternary pedology conducted by the Center for Southeast Asian Studies of Kyoto University from November 1968 to January 1969.

The author is deeply indebted to the National Research Council of the Thai Government and the Department of Geology of the Chulalongkorn University for the approval and the assistance for this research in Thailand. Thanks are also due to Dr. Takaya who assisted the author during the field survey and gave him helpfull advice. I wish to express thanks to Professors A. Komatsu, S. Morita and all of Kyoto Prefectural University for their support in this research study.

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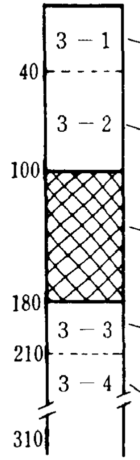
Fig. 4 Layer sequences of outcrops, descriptions and some properties of each layer

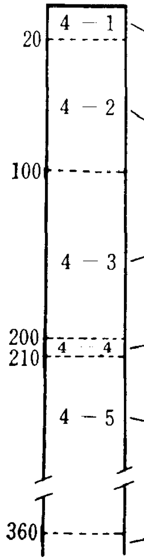
Depth cm	Sample number	Description	Mechanical composition (%) coarse sand	fine sand	silt	clay	silt/clay	Mineralogical composition of clay fraction** (%) Kaol	Ill	other 2:1	Characteristics of other 2:1 clay mineral	Half maximum breadth of peak of d_{001} of Kaoline (degree)	Mineral characteristics of coarse sand fraction*
		Location: Ca. 20km West from Lampang - Tak junction of Highway						Vegetation: deciduas trees & bushes					
80	1 − 1	Strong brown (7.5YR 5/6) (dry) sandy clay	39.5	26.6	7.9	26.0	0.30	90	+	10	Mt>Ver	0.84	PQ>RBr.Ang. >>WQ, Feld
160	1 − 2	White (10YR 8/2) (dry) sandy clay with few cloudy mottles	33.3	29.2	9.7	27.8	0.35	90	+	10	Mt>Ver	0.84	PQ>RBr.Ang. >>WQ, Feld
260	1 − 3	Pinkish white (2.5YR8/2) (dry) sandy clay with common large cloudy mottles and many irregular shaped laterite fragments	33.2	29.6	10.0	27.2	0.37	90	+	10	Mt>Ver	0.84	PQ, YBr. Ang. >> WQ, Feld
		Location: Ca. 15km West from Lampang - Tak junction of Highway						Vegetation: paddy field					
15	2 − 1	Dark grayish brown (2.5Y4/2) (dry) sandy clay loam with common mottles	42.8	29.7	11.5	16.0	0.72	70	25	5	Mt>Ver	0.81	PQ>Feld, WQ, RBr. Ang.
35	2 − 2	Olive yellow (2.5Y6/6) (dry) sandy loam with common mottles	49.4	29.2	9.6	11.8	0.81	70	25	5	Mt>Ver	0.81	PQ>Feld, WQ, RBr. Ang
55	2 − 3	Olive yellow (2.5Y6/6) (dry) sandy loam with common mottles	55.0	26.2	5.4	13.4	0.40	80	15	5	Mt>Ver	0.84	PQ, RBr. Ang. >WQ> Feld
75	2 − 4	Accumulation layer of laterite fragments	44.8	18.1	7.8	29.3	0.27	85	10	5	Mt>Ver	0.85	PQ, RBr. Ang. >WQ> Feld
		Hard laterite pan with gravels (ground water type)											

Location: Ca. 9km West Lampang - Tak junction of Highway Vegetation: bushes



Light browgray (10YR6/2) (dry) sandy loam	36.2	42.4	9.7	11.7	0.83	80	15	5	Mt=Ver	0.84	PQ>RBr.Ang. WQ, Feld
Light gray (10YR7/2) (dry) sandy clay loam with profuse mottles	35.1	33.6	8.2	23.1	0.36	80	10	10	Mt=Ver	0.92	PQ>RBr.Ang. >WQ, Feld
Hard to loose laterite pan with gravels (ground water type?)											
White (N8) (dry) light clay with many concentration & mottles	35.8	17.4	10.6	36.2	0.29	80	10	10	Ver>Mt	0.99	WQ>Feld>> PQ, RBr. Ang.
White (2.5Y8/2) (moist) heavy clay with many mottles	8.2	19.2	16.7	55.9	0.30	70	20	10	Ver>Mt	0.97	RBr. Ang.>> PQ,WQ,Feld

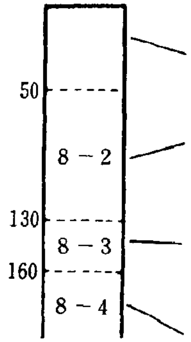
Location: Ca. 500m east from No. 2 Vegetation: bushes



Light brownish gray (10YR6/2) (dry) loamy sand	52.4	31.8	7.1	8.7	0.82	85	10	5	Ver>Mt	0.75	PQ>RBr.Ang. >WQ, Feld
Pinkish gray (7.5YR6/2) (dry) sandy clay loam	50.6	25.9	5.5	18.0	0.31	90	5	5	Ver>Mt	0.77	PQ>RBr.Ang. >WQ, Feld
Pinkish white (7.5YR8/2) (dry) sandy clay with common mottles	45.8	21.4	5.0	27.8	0.18	90	5	5	Ver>Mt	0.83	PQ>RBr.Ang. >WQ, Fled
White (10YR 8/2) (dry) sandy clay with mottles and profuse mangan concretions	35.7	26.6	2.9	34.8	0.08	90	5	5	Ver>Mt	0.78	PQ>RBr.Ang. >Mn-conc> WQ, Feld
White (10YR 8/2) (dry) sandy clay with many mottles	40.7	23.6	6.7	29.0	0.23	90	5	5	Ver>Mt	0.78	PQ>RBr.Ang. >Feld>WQ
Coarse sand with gravels											

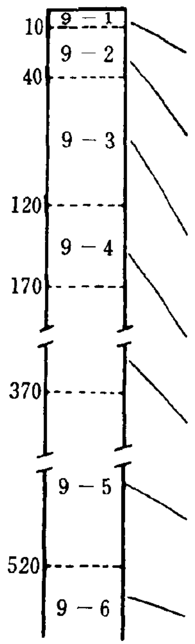
Depth cm	Sample number	Description	Mechanical composition (%) coarse sand	fine sand	silt	clay	silt/clay	Mineralogical composition of clay fraction** (%) Kaol	Ill	other 2:1	Characteristics of other 2:1 clay mineral	Half maximum breadth of peak of d_{001} of kaoline (degree)	Mineral characteristics of coarse sand fraction*
		Location: North of Ban Lampang Luang Vegetation: paddy field											
20	5−1	Light gray (2.5Y7/2) (dry) light clay with common fibrous mottles	9.4	23.0	40.0	27.6	1.45	55	20	25	Ver>Mt	0.83	RBr. Ang.>> PQ,WQ,Feld >Mica
40	5−2	Gray(N5) (moist) light clay with many round to subround Mn-concretions	13.1	25.5	19.6	41.8	0.47	60	15	25	Ver=Mt	1.02	Mn-conc,Feld >PQ,WQ, RBr.Ang.
	5−3	Gray (N5) (moist) well indurated sand with Mn-films and irregular shaped Mn-concretions	71.3	18.7	5.4	4.6	1.17	60	15	25	Ver=Mt	1.14	Gray rock frag. >>PQ, Mn-conc.
		Location: Ban Huai Lo Vegetation: paddy field											
10		Plow layer of paddy soil											
15		Gley horizons under Plow layer											
	6−1	Grayish brown (2.5Y5/2) (moist) Clay loam with mottles and common concretions	27.9	30.8	24.4	16.9	1.44	50	15	35	Mt>Ver	0.73	RBr. Ang.> PQ,WQ>> Feld
		Location: Ban Huai Lo Vegetation: paddy field											
15	7−1	Yellowish brown (10YR5/4) (moist) light clay with mottles	5.4	12.5	40.8	41.3	0.99	45	25	30	Ver>Mt	0.73	YBr. Ang.> WQ, Feld, Conc.
	7−2	Dark grayish brown (2.5Y4/2) (moist) silty clay with mottles & few concretions	2.1	7.9	48.9	41.1	1.17	45	25	30	Ver>Mt	0.73	Conc.>>Feld, WQ
		Location: Ban Phok Nang (North of Lampang City)											
	10−1	Yellowish brown (10YR5/4) (moist) heavy clay with mottles and concretions	3.6	6.1	43.9	46.4	0.95	45	35	20	Ver>Mt	0.74	Conc.

Location: Ban Kao Son (West of Ko Kha)



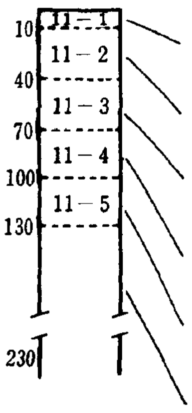
Strong brown (7.5YR6/4) (dry) sandy loam											
White (10YR8/2) (dry) sandy clay loam with mottles	45.1	30.2	6.5	17.2	0.38	45	40	15	Mt=Ver	0.73	PQ>RBr.Ang. >WQ,Feld
Accumulation layer of laterite fragments and concretion with sandy clay	29.4	23.2	13.1	32.3	0.40	50	25	25	Mt=Ver	0.79	PQ, RBr.Ang. >Feld> Micas >Conc.
Pinkish white (2.5YR8/2) (dry) sandy clay loam with lime concretions and micas	52.8	15.9	7.6	23.7	0.32	55	20	20	Mt>Ver	0.83	WQ>Feld> Micas>PQ

Location: Ban Tha Lo (North of Lampang City)



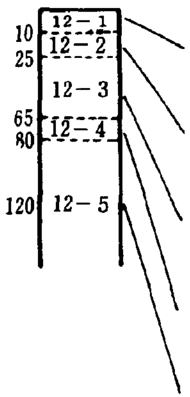
Light brownish gray (10YR6/2) (dry) loamy sand	47.2	39.4	7.4	6.0	1.23	70	20	10	Ver>Mt	0.71	WQ>Feld> PQ>>Conc.
Pinkish white (7.5YR 8/2) (dry) sandy loam	44.5	38.3	9.9	7.3	1.36	75	15	10	Ver>Mt	0.72	WQ>Feld> PQ>>Conc.
Reddish yellow (7.5YR7/6) (dry) sandy loam with many gravels	52.6	25.6	8.5	13.3	0.64	75	15	10	Ver>Mt	0.83	WQ, Feld, PQ >>Conc.
Gravel layer with light red (10R6/8) (dry) light clay	39.6	14.4	7.1	38.9	0.16	80	15	5	Ver>Mt	0.74	WQ, Feld, PQ >>Conc.
Weathered gravel layer											
White (N8) (dry) light clay with many gravel sand mottles	30.0	21.6	11.4	37.0	0.31	85	15	+	Ver>Mt	0.99	Conc, WQ> Feld, PQ
White (N8) (dry) light clay with mottles and gravels	39.8	13.0	8.7	38.5	0.23	80	15	5	Ver>Mt	0.96	WQ>Feld >>YBr.Ang.

Location: Ca. 9 km from Lampang City on the Chae Hom Road



Depth cm	Sample number	Description	Mechanical composition (%) coarse sand	fine sand	silt	clay	silt/clay	Mineralogical composition of clay fraction** (%) kaol	Ill	other 2:1	Characteristics of other 2:1 clay mineral	Half maximum breadth of peak of d_{001} of kaoline (degree)	Mineral characteristics of coarse sand fraction*
		Grayish brown (2.5Y 5/2) (dry) sandy loam	34.9	29.7	13.9	21.5	0.64	50	20	30	Mt>Ver	0.72	PQ>WQ>Conc.>Feld
		Yellow (10YR7/6)-yellowish brown (10YR5/4) (dry) sandy loam	35.5	30.4	13.5	20.6	0.65	50	15	35	Mt=Ver	0.72	PQ>WQ>Conc.>Feld
		Light gray (2.5Y7/2) (dry) clay loam	31.9	29.5	15.7	22.9	0.68	50	15	35	Mt=Ver	0.73	PQ>WQ>Conc.>Feld
		Light gray (2.5Y7/2) (dry) sand with patch of black (5Y2/2) (dry) clay loam	26.4	30.2	20.5	22.9	0.89	50	15	35	Mt=Ver	0.73	PQ>WQ>Conc.>Feld
		Accumulation zone with sandy clay and gravels						50	15	35	Mt=Ver	0.81	PQ>WQ>Conc.>Feld
		Gravel layer											

Location: Ca. 15 km from Lampang City on the Chae Hom Road



Depth cm	Sample number	Description	coarse sand	fine sand	silt	clay	silt/clay	kaol	Ill	other 2:1	Characteristics of other 2:1 clay mineral	Half maximum breadth of peak of d_{001} of kaoline (degree)	Mineral characteristics of coarse sand fraction*
		Pinkish gray (7.5YR6/2) (dry) clay loam	21.8	19.5	33.8	24.9	1.40	55	15	30	Mt>Ver	0.70	R.Ang.>Conc.
		Pinkish gray (7.5YR6/2) (dry) light clay	16.3	15.0	33.5	35.2	0.95	55	15	30	Mt>Ver	0.70	R.Ang.>Conc.
		Reddish brown (5YR5/6) (dry) light clay	14.8	16.0	32.1	37.4	0.86	60	15	25	Mt>Ver	0.70	R.Ang.>Conc.
		Reddish brown (2.5YR4/4) (moist) heavy clay with mottles and concretions	12.0	12.1	27.4	48.5	0.56	60	15	25	Mt>Ver	0.70	R.Ang.>Conc.
		Accumulation zone of lateritic fragments and concretions	17.0	12.7	19.1	51.2	0.37	60	15	25	Mt>Ver	0.70	R.Ang.>Conc.

Location: Ca. 3.5 km from Lampang-Ngao Road to Mae Nam Wang Irrigation Project　　Vegetation: deciduas trees & bushes

30	13－1	Brown to dark brown (10YR3/4) (dry) clay loam with few shale fragments	22.6	27.5	28.9	21.0	1.38	35	20	45	Ver>Mt	0.90	Shale>Conc.> RBr.Ang.
70	13－2	Yellowish red (5YR3/6) (dry) light clay with weathered shale	15.5	14.7	36.6	33.2	1.10	35	20	45	Ver>Mt	1.04	Shale>RBr. Ang.>Conc.
120	13－3	Very pale brown (10YR7/4) (dry) weathered shale	42.6	36.7	13.7	7.0	1.96	25	20	55	Ver>Mt	0.96	Shale
	13－4	Very pale brown (10YR7/4) (dry) weathered shale with lime concretions	42.8	37.4	13.7	6.1	2.24	25	20	55	Ver>Mt	0.96	Shale

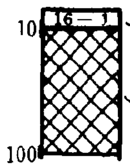
Location: Mae Nam Wang Irrigation Project

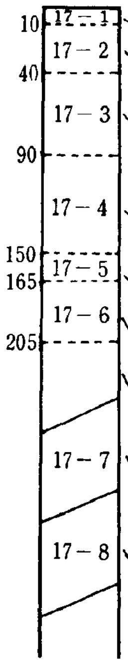
70	14－1	White (10YR8/2), pink (7.5YR7/4) reddish yellow (7.5YR6/8) (dry) light clay with concretions	5.5	22.6	30.0	41.9	0.72	55	25	20	Ver>Mt	0.90	PQ,YBr.Ang. >Conc.
90	14－2	Very pale brown (10YR8/4) (dry) light clay with profuse concretions	10.4	25.0	28.0	36.6	0.77	55	30	15	Ver>Mt	1.04	RBr.Ang.> PQ>>WQ, Feld
	14－3	Pale yellow (2.5Y8/4) (moist) light clay with mottles & concretions	3.7	22.3	32.4	41.6	0.78	50	30	20	Ver>Mt	0.96	YBr.Ang.> WQ,Feld Conc.
600	14－4	Very pale brown (10YR8/4) (moist) light clay with mottles and Ca-nodules	12.5	16.5	32.0	39.0	0.82	45	25	30	Ver>Mt	0.96	Ca-nodules> Feld,WQ

Location: North of Wa Yai

30	15－1	Light red (2.5YR6/8) (dry) heavy clay	3.4	4.3	12.3	80.0	0.15	55	20	25	Ver>Mt	0.83	—
100	15－2	White (10YR8/2) (dry) heavy clay with yellow mottles	1.6	4.2	20.0	74.2	0.72	50	20	30	Ver>Mt	0.77	—
	15－3	Light gray (5Y7/2) (dry) heavy clay with rock structure	0	0.5	8.0	91.5	0.09	50	20	30	Ver>Mt	0.73	—

Depth cm	Sample number	Description	Mechanical composition (%) coarse sand	fine sand	silt	clay	silt/clay	Mineralogical composition of clay fraction** (%) kaol	Ill	other 2:1	Characteristics of other 2:1 clay mineral	Half maximum breadth of peak of d_{001} of kaoline (degree)	Mineral characteristics of coarse sand fraction*
		Location: North of Wa Yai											
		Grayish brown sandy loam	37.6	39.8	12.9	9.7	1.33	60	20	20	Ver>Mt	0.60	PQ>RBr.Ang. >Feld, WQ, Conc.
		Honey comb structured laterite with gravels											
		Location: Ca. 4 km northeast of Amphoe Bang Na											
		Reddish yellow (7.5YR8/6) (dry) sandy loam	27.5	55.4	9.5	7.6	1.25	70	10	20	Mt>Ver	0.50	PQ>WQ> Feld> BlBr.Ang.
		Reddish yellow (7.5YR7/8) (dry) sandy loam	30.8	47.4	9.8	12.0	0.83	70	5	25	Mt>Ver	0.50	PQ>WQ> Feld> BlBr.Ang.
		Yellowish red (10YR5/8)(dry) light clay with laterite fragments and gravels (upper hard laterite pan)	35.5	19.3	7.9	37.3	0.21	70	10	20	Mt=Ver	0.63	BlBr.Ang.> PQ,WQ>Feld
		Yellow (10YR7/6) reddish yellow (5YR6/8) (dry) light clay with gravels and concretions	25.1	30.0	12.3	32.6	0.38	65	10	25	Ver>Mt	0.67	PQ,WQ>Feld, BlBr. Ang.
		Yellowish red (5YR4/8), (5YR5/8) (dry) light clay with many weathered gravels and laterite fragments	16.0	30.8	15.3	37.9	0.40	65	10	25	Ver>Mt	0.76	WQ>Feld> PQ>YBr.Ang.
		Strong brown (7.5YR5/8) (dry) light clay with mottles and gravels	24.6	29.1	13.2	33.2	0.40	60	10	30	Ver>Mt	0.69	WQ>Feld> YBr.Ang.>PQ
		Coarse sand and pebble stone											
		Reddish weathered rock (heavy clay)	0	1.2	28.0	70.8	0.40	50	25	25	Ver>Mt	0.51	—
		White weathered rock (heavy clay)	0	3.9	24.9	71.2	0.35	50	25	25	Ver>Mt	0.51	—





Location: Ban To

	18-1	Brown to dark brown (7.5YR4/4) (dry) clay loam	6.6	45.2	33.3	13.9	2.40	40	25	35	Ver>Mt	0.61	WQ,Feld
	18-2	Pinkish gray (7.5YR7/2) (dry) heavy clay with mottles and concretions	3.4	7.5	41.6	47.5	0.88	40	20	40	Ver>Mt	0.61	WQ>Feld> Conc.
300		White (10YR8/2) (dry) heavy clay with mottles	9.0	13.5	31.3	46.2	0.68	45	25	30	Ver>Mt	0.64	WQ>Feld> Conc.
450	18-3	White (10YR8/2) (dry) light clay with profuse concretions	17.1	15.3	30.0	37.6	0.80	50	25	25	Ver>Mt	0.69	WQ>Conc.> Feld>PQ
510 / 520	18-4 / 18-5	Gray (N8) (dry) light clay with mottles and concretions	12.6	16.2	31.4	38.8	0.81	55	25	20	Ver>Mt	1.05	PQ,WQ>Feld, Ca-nodule, Conc.
580		Well indurated coarse sand and gravels with mottles and Ca-nodules											

Location: Ban Nong

19-1	Dark Yellowish brown (10YR4/4) (moist) silty clay with mottles and concretions	2.2	10.2	47.5	40.1	1.18	50	20	20	Ver>Mt	0.57	—

Location: Ban Wang Phrau

	20-1	Brown (7.5YR5/4) (dry) silty clay with mottles	1.3	21.0	47.8	26.9	1.80	40	30	30	Ver=Mt	0.63	—
200	20-2	Brown (7.5YR5/4) (dry) silty clay with carbon and brick fragments	1.0	22.2	41.8	34.0	1.23	40	30	30	Ver=Mt	0.57	—
250	20-3	Brown to dark brown (7.5YR4/2) (dry) silty clay with mottles	0.5	12.0	46.7	40.8	1.14	40	20	40	Ver=Mt	0.57	—

* PQ: Pink quartz, WQ: White quartz, Feld: Feldspars, Conc.: concretions, RBr.Ang., YBr.Ang., BlBr.Ang.: perhaps Quartz stained with iron colored Reddish Brown, Yellowish Brown and Blackish Brown

** Kaol: Kaolinin minerals, Ill: Illite, Ver: Vermiculite, Mt: Montmorillonite